

Assessing Beaked Whale Reproduction and Stress Response Relative to Sonar Activity at the Atlantic Undersea Test and Evaluation Center (AUTECH)

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LONG-TERM GOALS

Atypical mass strandings and behavioral responses of beaked whales have been correlated with exposure to naval sonar (e.g. Simmonds and Lopez-Juraco 1991; Frantz 1998; Evans and England 2001), highlighting a need to understand the potential physiological impacts to individual whales and if these in turn represent a biologically significant threat to exposed populations. The long-term goal of this study is to assess glucocorticoid levels from blubber biopsies of beaked whales and other odontocetes, to assess stress levels relative to sonar exposure. Specifically, the project aims to collect biopsy samples at the U.S. Navy's Atlantic Undersea Test and Evaluation Center (AUTECH) in the Andros-AUTECH Operating Area where fleet readiness training involves regular use of mid-frequency active sonars, and compare the levels to those measured in biopsies collected from control populations within the Bahamas region that are less exposed to sonar activity. In parallel, pregnancy states will be ascertained via blubber progesterone levels in both groups of animals to investigate whether there is a relationship between sonar activity, stress measures, and reproductive rates, to assess population-level impacts.

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OBJECTIVES

The primary objectives of the study are:

- 1) To assess pregnancy rates from progesterone concentrations in blubber biopsies relative to sonar activity, and relate these to stress levels measured from glucocorticoid concentrations in the same tissue for Blainville's beaked whales and sperm whales.
- 2) To collect photo-identification data to monitor repeated sampling of individuals, construct sighting histories and identify consistent associates as covariates for stress analyses; and to document successful calving events for comparison to hormone-derived pregnancy rates.

APPROACH

The experimental design of this study is based on a population comparison: to compare beaked whale and sperm whale stress levels and pregnancy rates between areas with contrasting sonar activity: at the U.S. Navy's Andros-AUTEC Operating Areas and off the southwest coast of Abaco Island and other regions throughout the Great Bahama Canyon (Figure 1).

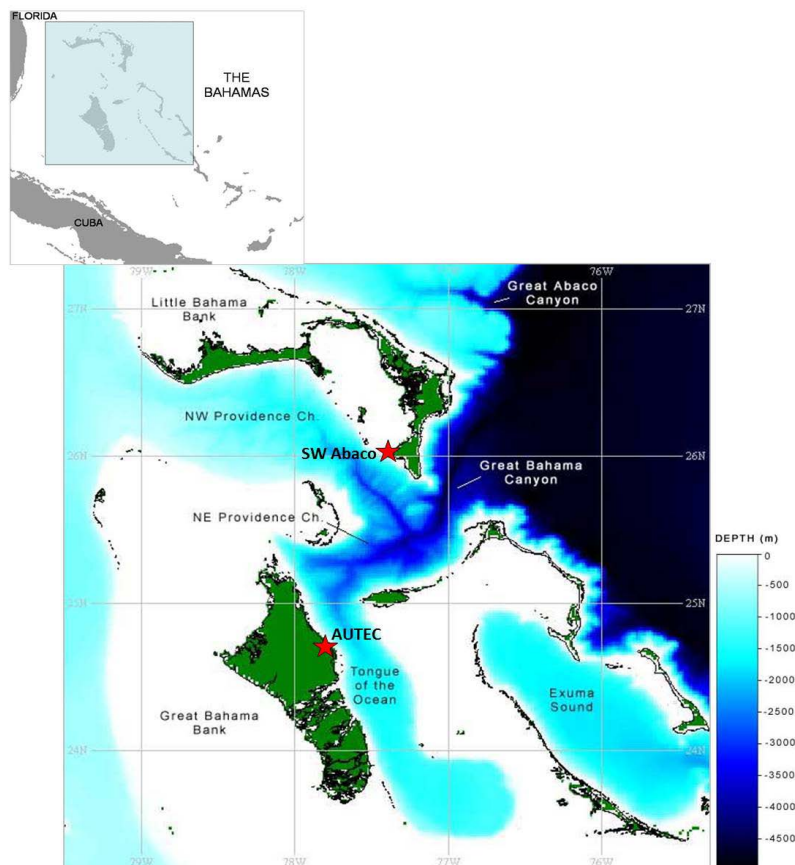


Figure 1. Map of the northern Bahamas showing the location of the two areas where blubber biopsy samples are being collected: AUTEC and SW Abaco. Both lie within the Great Bahama Canyon, a submarine canyon that reaches depths of more than 4000m. Additional sampling is occurring throughout the canyon region.

Stress levels for whales at AUTECH are being evaluated using biopsy samples collected before scheduled Submarine Commanders Courses (SCC) as part of an N45-funded satellite tagging study. Five field efforts are planned under this study, in April/May 2011-13 and Oct/Nov 2011-12. Reproductive rates will be examined relative to measured stress levels and sonar activity on the range during the preceding months through collaboration with David Moretti at the Naval Undersea Warfare Center. A further 15-day summer sampling effort has also been proposed at AUTECH in 2012 and 2013. In addition, three 15-day field efforts are planned in the control area at SW Abaco, spanning May 2011- May 2013, closely matching the timing of the spring SCC at AUTECH. These control samples are being augmented by samples collected during a concurrent annual SERDP-funded sightings-survey around the northern Bahamas, as well as samples collected opportunistically as part of the ONR-funded Bahamas Beaked whale Ecology Study (N000140710120). The species targeted are Blainville's beaked whale (*Mesoplodon densirostris*) and sperm whale (*Physeter macrocephalus*), but samples from Cuvier's beaked whales (*Ziphius cavirostris*) are also of direct interest.

Using AUTECH's instrumented array of bottom-mounted hydrophones on the Weapons Range, beaked whales and other odontocetes can be monitored and localized in real time by passive acoustic detection of their echolocation clicks (DiMarzio *et al.* 2008). Acoustic technicians from the Naval Undersea Warfare Center relay real-time cetacean localizations using the marine mammal monitoring system at AUTECH and direct observers on a 6.8 m rigid-hulled inflatable (RHIB) to the whales, increasing the opportunities for locating animals and obtaining biopsies. No such array exists off SW Abaco Island; so instead, boat-based surveys are concentrated in areas of known higher density of beaked whales, identified from over a decade of research in the area (Claridge 2006). A hand-held hydrophone is deployed to detect foraging sperm whales. Combined these approaches increase opportunities for finding animals off Abaco Island.

When animals are located, remote biopsy sampling (e.g. Hooker *et al.* 2001) is being used to obtain skin and blubber biopsies. Stress levels are being examined relative to sonar activity by measuring glucocorticoid concentrations in blubber biopsies. Pregnancy state will also be assessed by measuring progesterone concentrations in blubber (Kellar *et al.* 2006; Trego and Kellar 2009), and pregnancy rates will be examined relative to measured stress levels by comparison between samples collected at AUTECH and the control area around Abaco.

Photo-identification data are providing a record of all individuals sighted, and being used to build sighting histories, using new data and the existing BMMRO database. These data will provide information on ranging patterns and demographics that can serve as covariates for analysis of stress patterns. Similarly, photo-identification data will be used to evaluate the stability of individual associations to identify consistent associates that may have similar exposure and stress levels. Longitudinal photo-identification records will also enable documentation of successful calving events, to compare with hormone-derived pregnancy rates.

WORK COMPLETED

Field Effort

During FY11 vessel-based surveys were conducted at AUTECH (13 days) and at SW Abaco (13 days) in April and May 2011 (Figure 2). During both time periods efforts were somewhat hampered by inclement weather, and at AUTECH, also by restrictions in gaining access to the instrumented hydrophone array on the Weapons Range because of range safety concerns. As a result, vessel surveys were possible for only six of thirteen days that the field team was on site at AUTECH, and seven of

thirteen days at SW Abaco, in conditions that were sub-optimal for locating and closely approaching beaked whales.

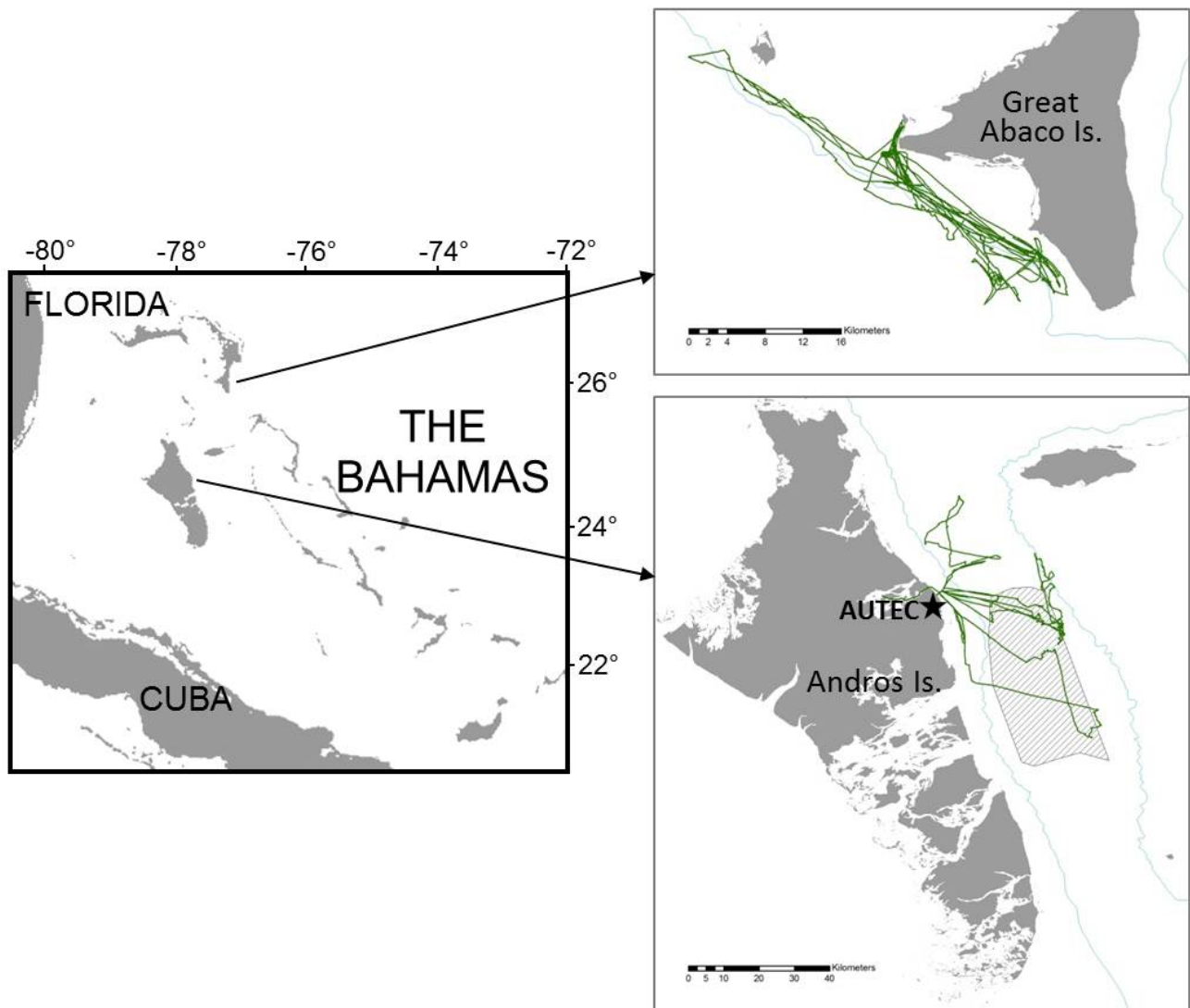


Figure 2. Vessel tracks (in green) show survey efforts off SW Abaco Island (top right) and off AUTECH (bottom right) during FY11. The 1000 m isobaths (blue lines) and the outer boundary of the instrumented hydrophone array at AUTECH (hatched area) are shown.

Table 1 summarizes the survey effort, as well as data collection for species that were seen, and whether or not blubber biopsies were obtained. The survey effort in both areas was very similar; AUTECH surveys covered 714 km of vessel track line, totaling 46.1 hours of visual search effort and the Abaco surveys covered 702 km of track line, totaling 50.7 hours of search effort. Additionally, there was opportunity to collect blubber biopsies off SW Abaco during dedicated vessel survey work associated with the Bahamas Beaked whale Ecology Study (ONR funded) and from throughout the northern Bahamas during a scheduled large vessel survey for the Behavioral Ecology of Deep-diving Odontocetes in the Bahamas (SERDP funded).

Table 1. Summary of field efforts to collect blubber biopsies at AUTECH and SW Abaco during FY11.

| DATE | EFFORT (KM) | EFFORT (HR) | SPECIES SEEN | GROUP SIZE | DUR. (MIN) | NO. BIOPSIES |
|-----------------------------------|----------------|----------------|---------------------------|---------------|---------------|-----------------|
| AUTECH - supported by N45 funding | | | | | | |
| 24-Apr-11 | 38 | 3.6 | none | n/a | n/a | 0 |
| 27-Apr-11 | 40 | 3.4 | none | n/a | n/a | 0 |
| 30-Apr-11 | 167 | 9.1 | Short-finned pilot whale | 22 | 69 | 5 |
| 04-May-11 | 172 | 9.9 | Sperm whale | 1 | 130 | 1 |
| | | | Short-finned pilot whale | 11 | 43 | 2 |
| 05-May-11 | 172 | 9.3 | Sperm whale | 9 | 109 | 2 |
| | | | Melon-headed whale | 40 | 22 | 0 |
| | | | Pygmy sperm whale | 2 | 1 | 0 |
| 06-May-11 | 125 | 11.1 | Sperm whale | 9 | 430 | 5 |
| | | | Melon-headed whale | 25 | 47 | 0 |
| | | | Melon-headed whale | 2 | 1 | 0 |
| | | | Fraser's dolphin | 3 | 32 | 0 |
| SW Abaco | | | | | | |
| 10-May-11 | 80 | 5.5 | Sperm whale | 1 | 34 | 0 |
| 11-May-11 | 151 | 10.0 | Atlantic spotted dolphin | 25 | 20 | 0 |
| | | | Dwarf sperm whale | 4 | 2 | 0 |
| | | | Dwarf sperm whale | 2 | 1 | 0 |
| | | | Pygmy sperm whale | 2 | 3 | 0 |
| 13-May-11 | 158 | 7.0 | Bottlenose dolphin | 4 | 8 | 0 |
| | | | Dwarf sperm whale | 1 | 1 | 0 |
| | | | Dwarf sperm whale | 1 | 1 | 0 |
| | | | Pygmy sperm whale | 2 | 12 | 0 |
| 14-May-11 | 83 | 9.1 | Blainville's beaked whale | 5 | 105 | 0 |
| | | | Fin whale | 1 | 107 | 1 |
| 17-May-11 | 20 | 2.2 | none | n/a | n/a | 0 |
| 20-May-11 | 61 | 7.0 | none | n/a | n/a | 0 |
| 21-May-11 | 148 | 9.9 | Blainville's beaked whale | 1 | 7 | 0 |
| | | | Pygmy sperm whale | 2 | 2 | 0 |

RESULTS

Data Collection

Despite similar survey effort, data collection differed at the two sites. From 24 April – 6 May, there were 10 cetacean sightings at AUTECH, but none of beaked whales. This was due to sea states being higher than Beaufort 3 on all days except one and we were not allowed access to the Weapons Range on that particular day. There were, however, three sperm whale sightings on the Weapons Range, during which we successfully collected 8 blubber biopsy samples. Additionally, we collected 7 biopsy samples from short-finned pilot whales (*Globicephala macrorhynchus*) which will be contributed to

population genetics and investigations into diet as part of the SERDP-funded Behavioral Ecology Study. In total, we spent 14.7 hours with animals during which 1236 photographs were taken. During the May 2011 field efforts at SW Abaco we had better success in finding beaked whales, due to protection from a lee shoreline, but we were unable to approach closely enough to obtain biopsy samples. We had 13 cetacean sightings, including 2 beaked whale groups and 1 sperm whale. We spent the majority of effort searching and only spent 5.1 hours actually with animals during which 613 identification photographs were taken. The only biopsy sample we collected was surprisingly from a fin whale (*Balaenoptera physalus*). The sample has been given to NOAA's Southwest Fisheries Science Center for a population structure study of this endangered species. However, the opportunity to use other DoD-funded projects as leverage for this study resulted in the collection of 5 blubber biopsies from Blainville's beaked whales and 2 from sperm whales off SW Abaco. The locations where blubber biopsies were collected at AUTEC and SW Abaco are shown in Figure 3.

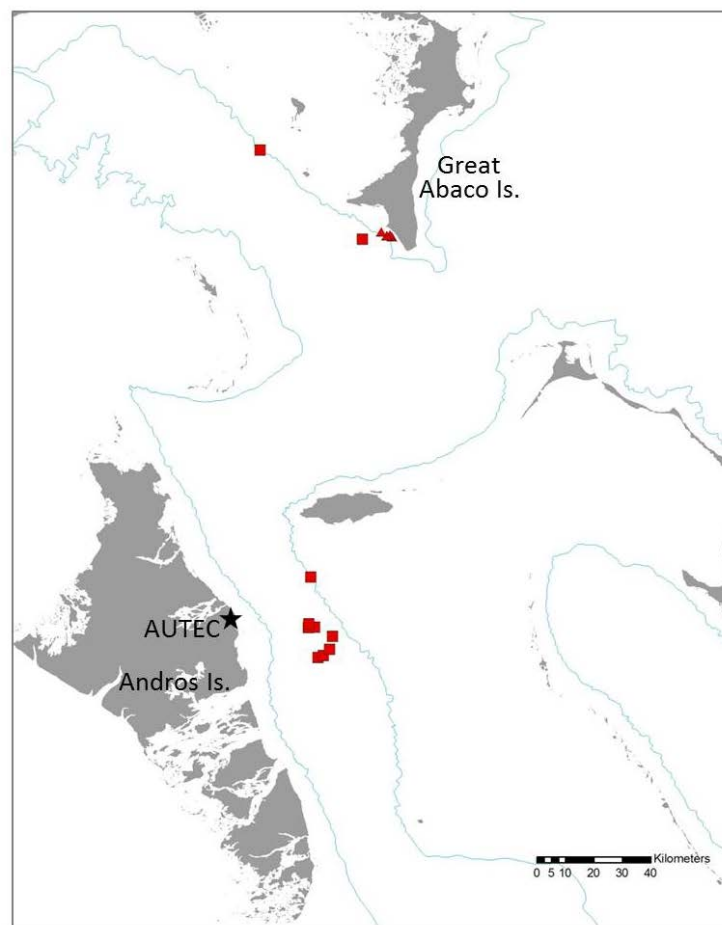


Figure 3. Map of the northern Bahamas showing locations where blubber biopsies were collected from Blainville's beaked whales (triangles) and sperm whales (squares) off AUTEC and SW Abaco during FY11. The 1000 m isobaths is shown by the blue lines.

All blubber biopsies obtained from Blainville's beaked whales were from individuals that have long-term sighting histories from the SW Abaco area. Md094 is an adult female and is one of the most frequently sighted beaked whales in the area. She was first sighted in 1998 at which time she had the characteristics of an immature whale (very little scarring) but was actually pregnant with her first offspring, born in 1999. She has been seen 37 times since and in 13 different years of the 14-year study and is known to have had at least one other offspring during that time. Md121 was also believed to be an immature animal when first photographed in 1999. She may have left the area as she matured as she has only been seen in 5 different years. She is now a reproductive female, and has had at least 1 offspring. Md134 was first seen as a calf in 1999, and believed to have been approximately 1 year old. This animal has remained in the SW Abaco study area during the time of sexual maturity. She has been seen 22 times since (9 different years) and with her first offspring in 2011. The males have slightly different sighting histories as there is less evidence of site fidelity (Claridge 2006). Md209 was first sighted in 2005 as a fully mature male and has been resighted 6 times since (seen in 5 different years). Md130 first seen in 1999 at which time he was still physically immature. He has been resighted only 4 times since and in 4 different years.

Preliminary matching of the sperm whale identification photographs have found that, with the exception of one possible match (Pm079), all of the other animals were not matched to the existing catalogue of sperm whales from the northern Bahamas, and are considered "new" animals in the area. Additional information for the biopsy data collected from these whales and the sperm whales are shown in Table 2.

Table 2. Summary of blubber biopsies collected from Blainville's beaked whales and sperm whales at AUTECH and SW Abaco during FY11.

| FIELDID | YR | MO | DA | LATD | LATM | LONGD | LONGM | LOCLTY | SEX | AGE CLASS | WHALE ID |
|---|------|----|----|------|-------|-------|--------|----------|-----|-----------|----------|
| Blainville's beaked whale - <i>Mesoplodon densirostris</i> | | | | | | | | | | | |
| 101117_Md1a | 2010 | 11 | 17 | 25 | 53.43 | 77 | 56.75 | SW Abaco | M | AD | Md209 |
| 110223_Md1a | 2011 | 02 | 23 | 25 | 53.79 | 77 | 16.01 | SW Abaco | F | AD | Md094 |
| 110223_Md2a | 2011 | 02 | 23 | 25 | 53.61 | 77 | 16.54 | SW Abaco | F | AD | Md121 |
| 110223_Md3a | 2011 | 02 | 23 | 25 | 53.63 | 77 | 16.6 | SW Abaco | M | AD | Md130 |
| 110223_Md4a | 2011 | 02 | 23 | 25 | 54.31 | 77 | 17.67 | SW Abaco | F | AD | Md134 |
| Sperm whale - <i>Physeter macrocephalus</i> | | | | | | | | | | | |
| 110206_Pm1a | 2011 | 02 | 06 | 26 | 9.79 | 77 | 40.63 | SW Abaco | F | AD | Ps518 |
| 110219_Pm1a | 2011 | 02 | 19 | 25 | 52.86 | 77 | 21.2 | SW Abaco | U | SA | Unk |
| 110504_Pm1a | 2011 | 05 | 04 | 24 | 48.7 | 77 | 30.98 | AUTECH | M | SA | Pm79? |
| 110505_Pm1a | 2011 | 05 | 05 | 24 | 33.4 | 77 | 29.59 | AUTECH | U | SA | Unk |
| 110505_Pm2a | 2011 | 05 | 05 | 24 | 33.77 | 77 | 28.616 | AUTECH | U | SA | Unk |
| 110506_Pm10a | 2011 | 05 | 06 | 24 | 39.23 | 77 | 30.31 | AUTECH | F | AD | Ps520 |
| 110506_Pm11a | 2011 | 05 | 06 | 24 | 39.06 | 77 | 31.48 | AUTECH | U | AD | Ps521 |
| 110506_Pm12a | 2011 | 05 | 06 | 24 | 39.81 | 77 | 31.39 | AUTECH | U | SA | Unk |
| 110506_Pm1a | 2011 | 05 | 06 | 24 | 37.41 | 77 | 26.91 | AUTECH | U | SA | Unk |
| 110506_Pm6a | 2011 | 05 | 06 | 24 | 34.93 | 77 | 27.4 | AUTECH | U | SA | Ps519 |

Hormone baselines

In preparation for the tissue processing and hormone measurements of these biopsies, relatively large blubber pieces (8x8cm) from three Cuvier's beaked whales, *Ziphius cavirostris*, (obtained from fresh strandings and fishery bycatch) are being used to optimize extraction and measurement procedures such that they will be more suitable for Blainville's beaked whale tissue. In preliminary analysis, Cuvier's beaked-whale blubber cortisol and progesterone values appear to be very similar to those measured in Delphinids. These results suggest little alteration will be needed to use our existing procedures on Blainville's beaked whale biopsies. Samples collected during FY11 have been imported to the United States and accessioned into the SWFSC tissue archive. The expectation is that once blubber biopsies are obtained from at minimum 30 free ranging individuals with adequate representation of both locations, we will begin laboratory analysis for our two population comparison.

IMPACT/APPLICATIONS

Improving our understanding of the population responses of beaked whales relative to sonar usage will aid the US Navy in assessing the potential need for additional mitigation practices for protected marine mammals. In particular, central questions for effective management and potential mitigation are whether sonar use causes detectable physiological stress responses and whether these responses are linked to biologically significant reductions in population health or condition.

This study will build upon ongoing research by Kellar *et al.* assessing stress levels in odontocetes associated with Navy sonar exercises at the Southern California Offshore Range (SCORE). Novel laboratory techniques, recently developed at Southwest Fisheries Science Center (Kellar *et al.* 2006, Kellar *et al.* 2009), are successfully being used to measure steroid hormones in marine mammal blubber indicating that these studies are both realistic and feasible. The combined results of these studies at both AUTEK and SCORE will provide greater power for assessing the extent and magnitude of stress responses in cetaceans exposed to sonar.

RELATED PROJECTS

Monitoring beaked whale movements during the Submarine Commanders Course using satellite telemetry

This project is a collaborative project between the Bahamas Marine Mammal Research Organisation, Southwest Fisheries Science Center and the Naval Undersea Warfare Center (David Moretti). Satellite telemetry is being used to monitor the movements and diving behavior of beaked whales and other odontocete cetacean species on the US Navy's Atlantic Undersea Test and Evaluation Center (AUTEK) range before, during and after sonar exercises in which multiple ships are using their tactical sonars. Field work during this project is providing opportunity to collect biopsy samples and photo-identification data at AUTEK. This project has been supported by the US Department of Defense (OPNAV N45 Dr. Frank Stone).

Behavioral ecology of deep-diving odontocetes in the Bahamas

This project is examining key aspects of the behavioral ecology of six Department of Defense priority species in The Bahamas. We will integrate data acquired through individual photo-identification, molecular genetics, fatty acid, persistent organic pollutant and stable isotope profiles, satellite telemetry and acoustic recordings to characterize the social structure, residency patterns, reproductive biology, diet, foraging ecology, and population structuring of key cetacean species. Field work during this project is providing opportunity to collect biopsy samples and photo-identification data from

throughout the northern Bahamas. The project has been supported by the Strategic Environmental Research and Development Program (US Department of Defense, Department of Energy and the Environmental Protection Agency).

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